Advanced Composite Dimensionally Stable Structures and Hybrid Composites Optical Systems and Kill Vehicle Sensors

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VANGUARD COMPOSITES

Technologies and Candidate Materials for Dimensionally Stable Structures

VANGUARD COMPOSITES

Stable Structures

- Aluminum/Aluminum Honeycomb
- Beryllium and Albemet
- Carbon/Carbon
- **Carbon Fiber Reinforced Plastic (CFRP)**
  - Carbon Fiber/Epoxy
  - Carbon Fiber/Cyanate Ester
- CSiC and CeSiC®
- Invar
- Metal Matrix Composites
- SiC
- Titanium

Mirrors

- Aluminum
- Beryllium and Albemet
- **CeSiC®**
- **Silica Foam (SLIMS™)**
- Ultra-low Expansion Glass (ULE®)
- Zerodur ®
- Pyrex (Borosilicate)
- Carbon Fiber Reinforced Plastic (CFRP)
- SiC
- Carbon/Carbon

The Highest Value Solution Involves Selecting Materials and Design Technology Combinations, which meet Mission Objectives of Performance, Cost, and Schedule

Hybrid Composites Solutions

Desired Material and Technology Characteristics of Optical Systems

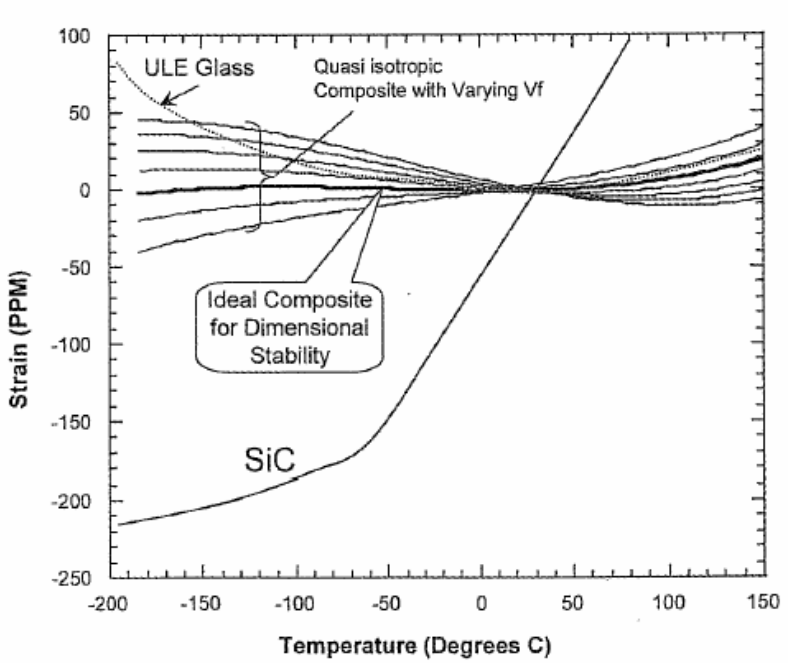
VANGUARD COMPOSITES

Structures with Optics

- Dimensionally Stable -Low CTE and constant over a wide operating temperature range
- Low Weight
- High Stiffness
- Good Strength
- High Fracture Toughness
- High Thermal Conductivity
- Heat Capacity
- Radiation Hardening
- Cleanliness and Contamination
- Long term stability, creep
- Storage Life
- Heritage
- Design Flexibility
- Manufacturability
- Low Cost
- Short Lead Time- Material Availability, Manufacturing

Mirrors (additional reqmts)

- Surface Accuracy
  - Operational
  - As-Manufactured
- Manufacturability
  - Ability to be Polished
  - Ability to apply Coatings



Ref: SAMPE Journal, Vol 38, pg 48, No.4 July/August 2002

GRAPHITE/CYANATE ESTER STABLE STRUCTURE TECHNOLOGY

VANGUARD COMPOSITES

- **Variety of Fiber and Resin Systems**, with a wide rage of material properties available, can be chosen and tailored for specific requirements
- **Near Zero** in-plane CTE over a wide temperature range Materials and
- Laminate Architecture is able to be **tailored for CTE (-.1 to .1 PPM/F)and Stiffness**
- **Lightweight** (.06 lbs/cu in), High specific stiffness
- **Design and Manufacturing Flexibility** for specific requirements
- **Low Cost** and **Short lead times**
- **Heritage Technology** – ground, air, and space

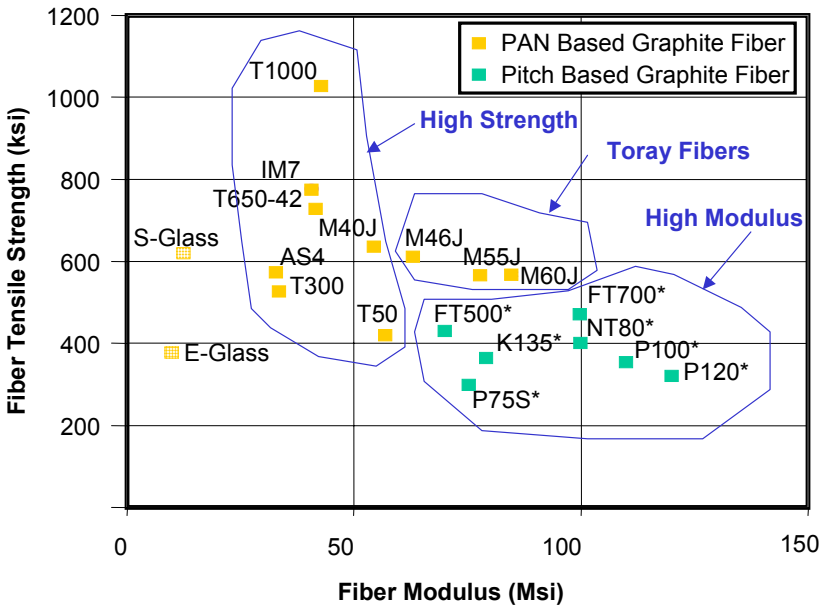
Material	E (Msi)	CTE (ppm/ F)	Weight Density (lbs/in3)	Poisson's Ratio	Thermal Conductivity (Btu/ft.hr. F)
Be	42.5	6.39	0.067	0.1	124.8
Graphite (Gr/CE)	15.6	-0.08	0.06	0.38	20.22
C/SiC(Cesic) [2]	32.6	1.389	0.095	0.14	69.12
ULE [3]	9.8	0.0167	0.079	0.17	0.757
Si [2]	18.85	1.389	0.084	0.24	85.53
Si Foam (SLMS) [2]	1.885	1.389	0.008	0.24	85.53
INVAR	28	0.7	0.28	0.29	43.913
MMC [1]	16.97	6.89	0.105	n/a	71.07
SiC [1,4]	67.44	1.33	0.116	0.21	114.4

*Tailorable

Caution: Material Properties alone should not be used as Figures of Merit in determining the Highest Value Solution. Exploit Design flexibility in conjunction with proper material selection.

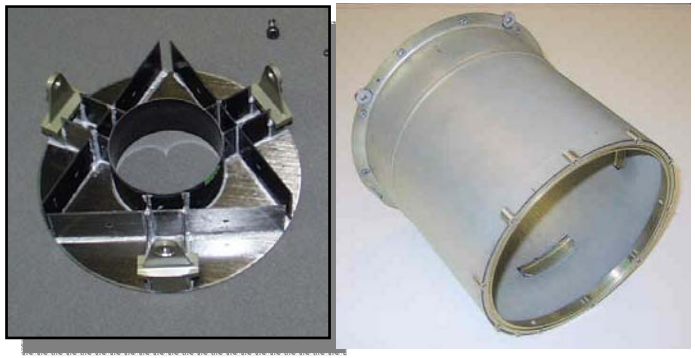
GRAPHITE/CYANATE ESTER STABLE STRUCTURE TECHNOLOGY

- Material System is chosen and tailored to meet performance and cost objectives
  - Fiber and resin
  - Prepreg resin content
  - Tape or woven fibers, tow size
  - Coatings –plating, co-cured foils, thermal, optical properties
  - Surface texture
- Design is tailored, engineered to meet interface, envelope, and performance requirements
  - Optimized gauge thickness (.0025 to several inches)
  - Discrete rib construction
  - Local customized reinforcement
  - Dual wall construction
  - Light weighting
  - Secondarily applied or bonded coatings and shielding
  - Cleanable surface textures and sealed surfaces
  - Flexibility in design, tailorability
  - Accommodates changes late in manufacturing



GRAPHITE/CYANATE ESTER STABLE STRUCTURE TECHNOLOGY

- Constructed from simple, well behaved, shapes
  - thin prepreg autoclave cured laminates
- Laminate details are layed up, cured, and machined to net or near net shape.
- Room Temperature Bonded Construction
  - Simple laminates bonded into complex structures
  - Eliminates joints and hardware
  - Allows for match bonding to meet very tight tolerances without high machining cost
  - Precision tooling locates critical interfaces
  - Lower residual stress
  - Design changeability and flexibility
- Bonded Metallic or Composite Fittings for Interfaces
  - Stiff, efficient load paths
  - Provides local reinforcement at highest loaded areas
  - Location and registration,repeatability
  - Alignment
  - Match Bonding reduces assembly tolerances and cost



GRAPHITE/CYANATE ESTER STABLE STRUCTURE TECHNOLOGY HERITAGE

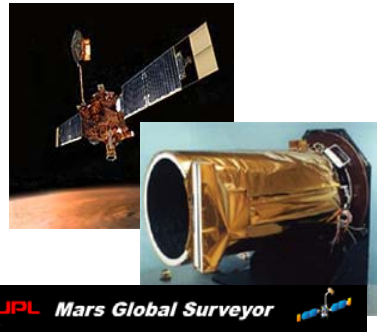
VANGUARD COMPOSITES

- Space Instruments and Sensors (examples)
  - NASA Chandra X-Ray Observatory Science Instrument Module [1]
  - NASA SOHO Ultraviolet Chronographic Spectrometer (UVCS) Telescope and Spectrometer [1]
  - Raytheon Moderate Imaging Spectrometer (MODIS) [1]
  - JPL Mars Observer [1]
  - Mars05 CTX [2]
- Airborne
  - Air Born Laser Beam Expander [1]
- Ground
  - Thermotrex ROBS Target Acquisition telescope [1]
  - Thermotrex TCATS Telescope
  - Raytheon Santa Barbara Engineering Development Optical Bench [2]

[3]

Chandra X-Ray Observatory

[3]



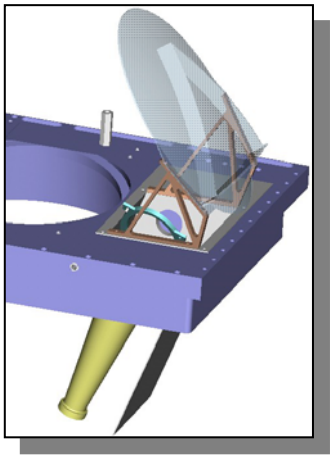
[3]

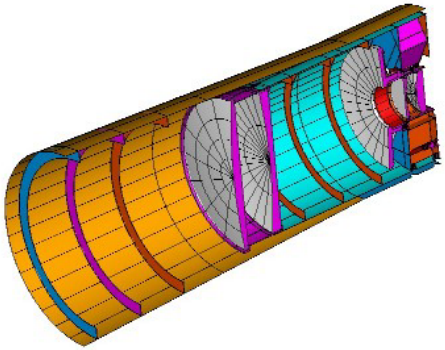
Notes:

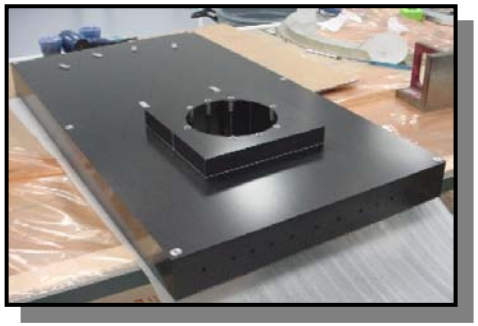
1. Engineered and Fabricated by Vanguard Composites
2. Engineered and Fabricated by Composite Optics, Inc
3. Ref: NASA Website

Recent Stable Structures Program Experience

- Raytheon SBRC - ABI Instrument Structure
- Raytheon SBRC - VIIRS Instrument Structure
- Northrop Grumman Corp - ATMS Instrument Structure Covers
- Kaiser Electro Optics/Malin – JPL MarsO5 CTX Camera Structure, Sunshade and Baffle
- Raytheon/MDA/AFRL – EKV Sensor Structure and Mirrors



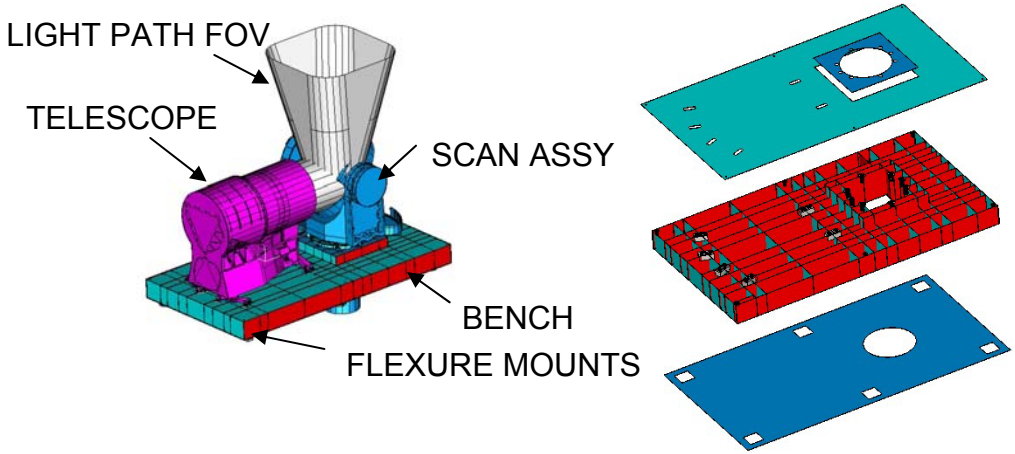


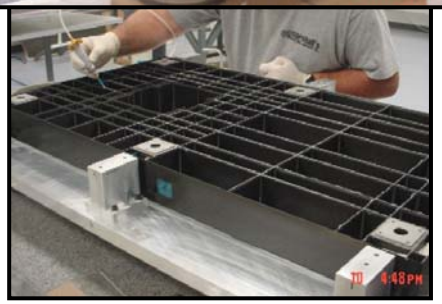


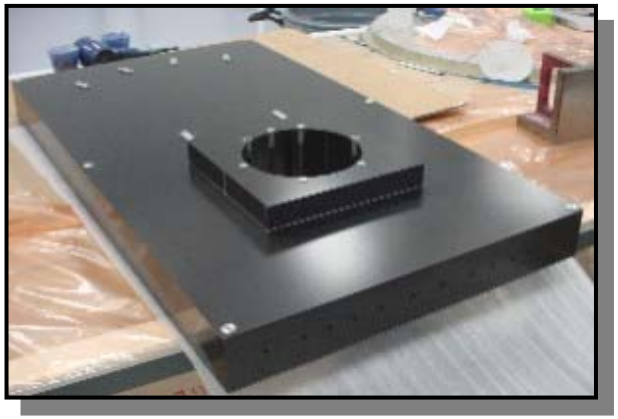
Optical Bench Engineering and Fabrication

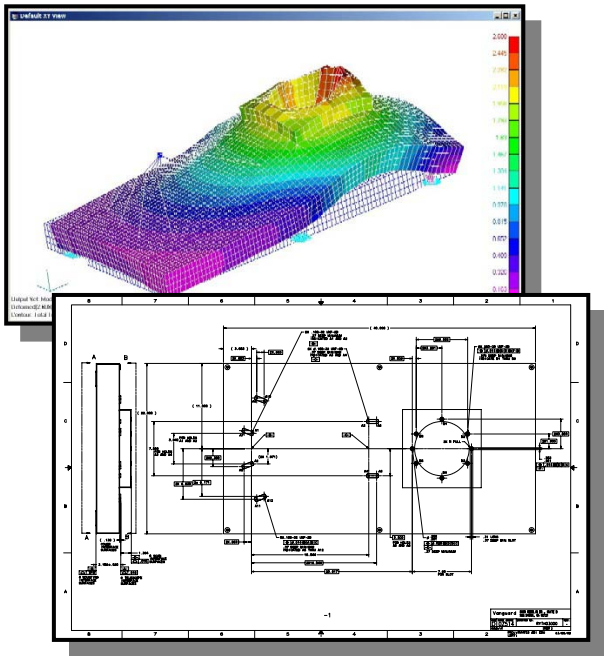
Contract: **EDU Optical Bench**
Customer: **Raytheon**
Vanguard Responsibilities:
- **Design, Analysis**
- **Fabrication**

Contract Value: **$80,000**
Duration: **Oct 01 – Jan 02**
- **4 Month Delivery**





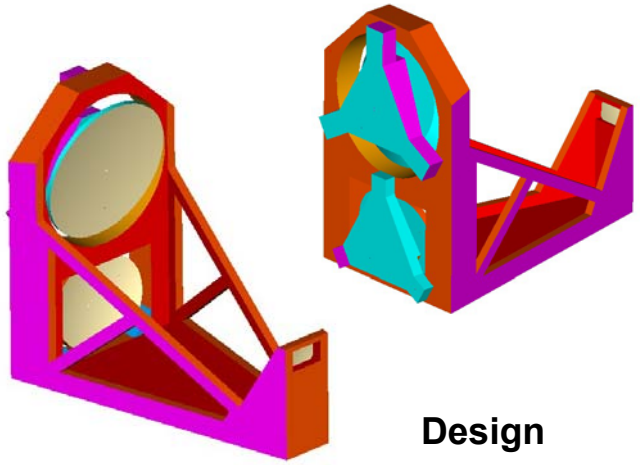




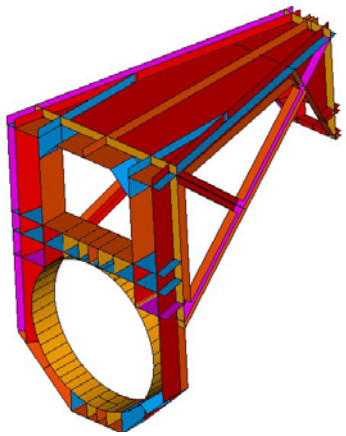
Three Mirror Telescope Structure Engineering

Contract: **ABI**
Customer: **Raytheon**
Vanguard Responsibilities:
- **Engineering Study**

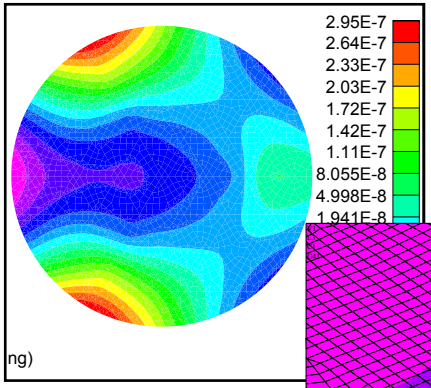
Contract Value: **>$60,000**
Duration: **Oct 01 – April 02**



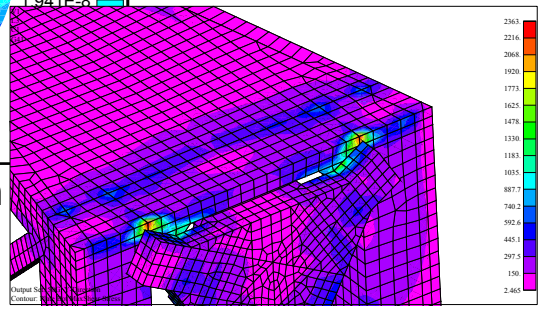
Design



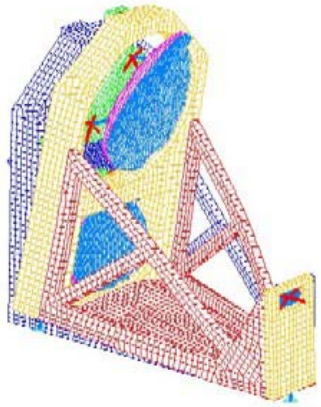
Manufacturability



Thermal Distortion Analysis



Strength Analysis



Modal Analysis

Contract No.: F29601-03-C-0046

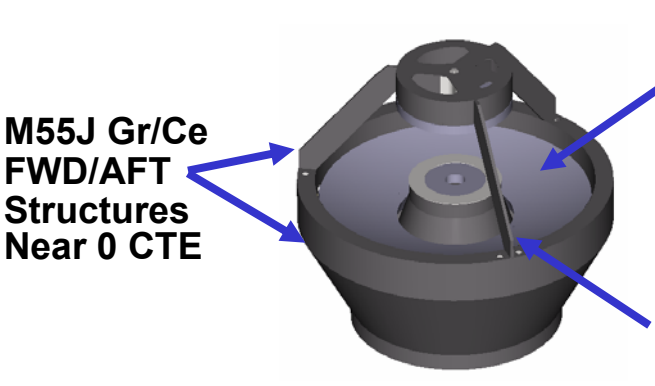
EKV Optical Sensor Hybrid Composites Results

VANGUARD COMPOSITES

REQUIREMENTS

- Optics Dimensional Stability (Temperature, 1-g sag)
- Structural (Stiffness, Interfaces)
- Low Outgassing/Contamination
- Nuclear Radiation Hardness
- Light Weight
- Low Cost and Producible

HYBRID COMPOSITE SOLUTION



Mfg Process: Prepreg Hand Layup/Autoclave, Room Temperature Bonded

PERFORMANCE

Mirror-Structure Concept	CTE (ppm/F)	Wt. lb	Freq. Hz
Baseline (Be)	6.4	6.4	373/850
Hybrid Composites:			
Gr/CE SLMS™	-.08/2.5	2.6	565/570
Gr/CE Cesic®	-.08/2.5	5.6	424/425

-<1/2 wt
-25% less 1g sag,
-40x better dimensional stability
-High Stiffness
-Manufacturability
- Lower Cost & Shorter Lead Time

Phase II Program

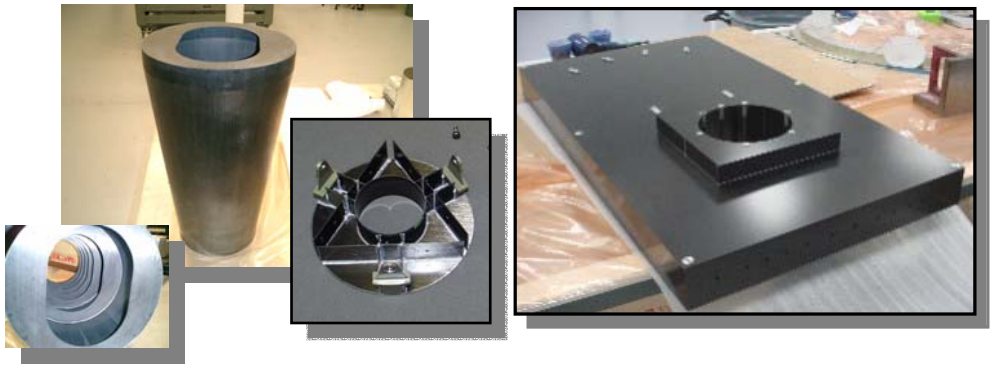
- Engineer Structure and Mirrors EKV Sensor Requirements
- Coupon Testing
- Fabrication
- Full scale testing

EKV Interceptor KV

Vanguard Team's Optics Composites Technologies

Vanguard Composites: Dimensionally-Stable Carbon Fiber Reinforced Composites

- Graphite Fiber/Cyanate Ester (Gr/CE)
- MARS05 CTX Camera
- JAMI Optical Bench



Schafer Corporation: SLMS™ Mirror Technology

- 90% Porous Si Foam Core CNC Machined to any Shape & ±0.002 in.
- Continuous CVD Poly Si Shell up to 2" Thick & 1m Dia.

Schafer Corporation: Cesic® Mirror Technology

- Infiltration of Porous C/C with Molten Si by Capillary Forces in High Temp Vacuum Process
- Densification & Partial Reaction of C-Matrix with Si to Form SiC